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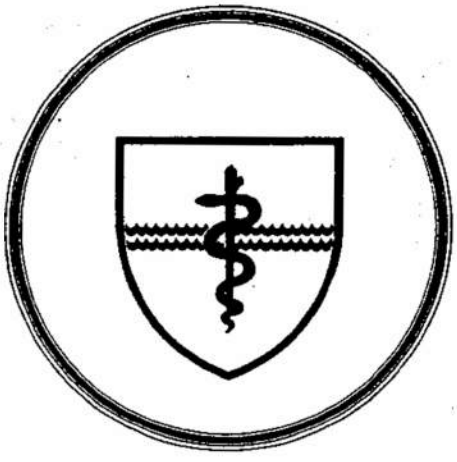

REPORT NO. 1087

LOW LEVEL WHITE LIGHTING FOR SUBMARINE CONTROL ROOMS

by

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Naval Medical Research and Development Command
Research Work Unit M0100.001-1023

Released by:

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Commanding Officer
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19 November 1986

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Problem

To compare the effectiveness of various arrangements of lighting intensities of low level white light (LLW) in submarine control rooms.

Findings

LLW was judged by the officers and men to be more desirable than red light. However, the intensity of the LLW had to be reduced below that obtained by a direct foveal match to the red. Moreover, two filter densities, producing two intensities of light, were necessary. Filter densities of 1.6 (transmittance = 2.5%) were rated most acceptable in most lighting fixtures, and filters of 2.1 density (transmittance = 0.8%) were required for lights which proved to be distracting and for those lights, such as those over the plotting tables, which must remain on at all times.

Application

These results are relevant for the specification of the densities of light filters to be substituted for red filters on submarines.

ADMINISTRATIVE INFORMATION

Investigation conducted under research Work Unit #M0100.001-1023, "Enhanced Visual Performance on Submarines." Manuscript was submitted for review on 30 September 1986 and approved for publication on 19 November 1986. It has been designated as NSMRL Report # 1087.

ABSTRACT

Several lighting arrangements of low level white lighting (LLW) were evaluated by the watch-standers in a submarine control room at sea. Specifications for neutral filters to replace the current red filters were based on the arrangement judged to be most satisfactory.

The desirability of eliminating the use of red light in submarine compartments at night and substituting low level white (LLW) light has been investigated in a series of studies which have been briefly summarized (1). Evaluations were first carried out in sonar compartments where the LLW was favorably received (2). A series of evaluations was next carried out in the control rooms of four submarines (3-6).

The LLW was almost unanimously rated by the officers and crew as being superior to the red. However, two problems were apparent. First, some of the crewmen judged the overall level of the LLW to be too bright. The intensity of the LLW was matched to the red light by direct viewing, and the resulting filter density was 1.3 (transmittance = 5 percent). However, the eye is relatively more sensitive to white light than to red in the periphery. Thus, when the observer is surrounded by light rather than looking at only a small stimulus area, the general ambient intensity seems to be greater. Many individuals thus wanted the LLW to be dimmer. The second problem was related to the first. Peripheral white light, such as that coming from the adjoining passageways, was more obtrusive than red and was sometimes distracting, again because the periphery of the eye is more sensitive to white than to red light.

Two crews (5,6) judged that the overall light level was satisfactory when it was made somewhat dimmer. It was still not completely clear, however, what the optimal reduction is, or if such an overall reduction would eliminate the distraction of the peripheral lights.

The purpose of this investigation was to compare and evaluate a variety of light levels and arrangements of lights in the control room at sea.

METHOD

Experimental Procedure

The first night of the study the control room was illuminated with the standard red light. On the following nights, the control room and adjoining spaces were illuminated with LLW using four different arrangements of light intensities; each lighting arrangement remained in effect for at least one night. Figure 1 shows the four arrangements. In the first (Fig. 1a), the control and sonar compartments were fitted with 1.3 density filters, and the adjoining navigation room and passageway were fitted with considerably dimmer 1.8 (transmittance = 1.6 percent) density filters. On the second night (Fig. 1b), the 1.8 filters were left in place and dimmer 1.6 filters (transmittance = 2.5 percent) were installed in the control and sonar rooms. Next, the 1.6 filters were installed everywhere (Fig. 1c). Finally, 2.1 filters (transmittance = 0.8 percent) were installed over the plotting tables and in a few selected fixtures whose light was distracting (Fig. 1d).

At the end of each of the two watches each night, the crew filled out questionnaires (Appendix A). They reported their watch station, how long they worked under the LLW, and judged whether or not the light that night was better than that of the previous night. The questions dealt with the desirability of the light, its brightness, ease of seeing, fatigue, and so on, after which final comments were solicited.

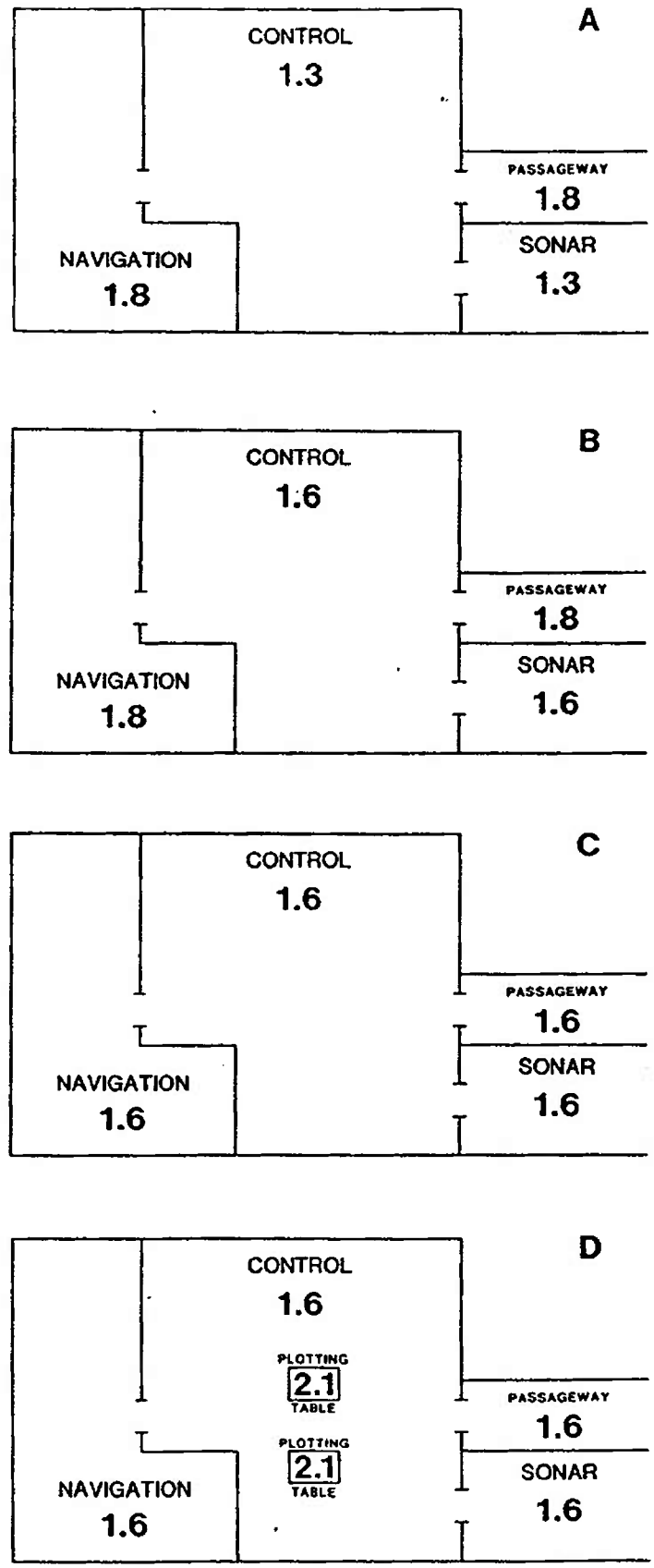

Figure 1. Arrangements of light intensities in the control room and adjacent spaces.

RESULTS

On the first night, the 21 watchstanders in the two watches were comparing the LLW with the red light. Eighty percent (17 men) rated the LLW as more desirable than the red, one rated it as the same, and three (14%) rated it as less desirable than the red. Most judged the LLW to be less fatiguing; only three said it was not less fatiguing, and three reported no difference. Also, only three felt that they could not see better with the LLW, and two said they could see equally well with the two lights. However, while 52% said the brightness of the LLW was "about right", 47% judged it to be too bright. And 60% said that some of the lights were distracting.

In the second arrangement, somewhat dimmer filters were installed in the control spaces. Observers compared 1.6 N.D. filters with the 1.3 N.D. filters. Forty-five percent said the light was the same as the previous arrangement, and 36% said it was better. Forty-five percent said they felt the same amount of fatigue with the two lights, and 36% reported less fatigue; only 18% reported more fatigue. But 54% still judged the light to be too bright, and 45% still felt that some of the lights were distracting.

In the third arrangement, 1.6 filters were installed everywhere. Forty percent of the respondents judged this to be worse than the previous arrangement. Half still reported some lights to be distracting.

Most of the complaints in these first three conditions came from the periscope operators and the watch-standers at the ballast and ship control panels. For the periscope operators, peripheral light was the problem; for the others, white light reflected off the faces of the guages was judged

to be more distracting than reflected red light.

In the final arrangement, relatively dense filters (2.1 density) were installed over those lights which were judged to be distracting. These were primarily the lights over the plotting tables, which must be on at all times, and a few fixtures which were missing the opaque shields alongside the red (or LLW) bulbs, and thus allowed light to shine through the edges of the fixtures. This arrangement produced general satisfaction.

DISCUSSION

Once again the overwhelming majority of observers judged the LLW to be preferable to red, particularly when its intensity is properly adjusted and sources of glare are dimmed. There is general agreement that the brightness match between red and white made with direct viewing produces ambient LLW light that is brighter than the red. The sonarmen did not complain of this, because they are not concerned with dark adaptation. Their main concern was that the ambient light be comfortable. They were happy with the original brightness match, simply because it was subjectively brighter and thus made their job easier.

In the control room, however, the over-riding concern is with dark adaptation for the periscope operator. He is sensitive to any increase in ambient brightness which may affect his ability to see at night, and he is particularly distracted by peripheral light, such as that from the plotting tables. Consequently, a much more subtle adjustment of intensity is required in the control room.

Dense 2.1 filters were installed over the plotting tables, because these lights must be left on when the rest of the lights are turned off. The resulting dimmer light

enables the periscope operator to see more clearly at night. It is noteworthy that the plotters reported that they were able to see the color-coding on the navigation charts amd could do their work satisfactorily even in this dim light.

These findings emphasize that the light fixtures in the control room must be carefully designed. Light coming out of the sides of the luminaires should be eliminated. The opaque shields on either side of the bulb which will be left on when the ambient light is dimmed must not be omitted, and egg-crate baffles to direct the light downward should also be installed.

We conclude, first, that the most desirable light in the control spaces of the submarine is LLW rather than red. Further, the LLW should be dimmer than that obtained by direct foveal matching of white to red. Second, it will be necessary to provide two densities of neutral filters to replace the red ones. The 1.6 N.D. filters should be used in most light fixtures, and 2.1 filters should be used in specific locations. This will introduce a small element of confusion into the installation of the LLW filters, but it should be quite possible to deal with this by appropriate filter markings. LLW installed in the control room will greatly improve the legibility of all printed material, particularly color coded material, and will lessen visual fatigue.

ACKNOWLEDGMENT

We thank the officers and crew of the USS PHILADELPHIA (SSN 690) for their cooperation in this study, and we especially thank ENS Steven Fisher-Jones for overseeing the study at sea.

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APPENDIX

QUESTIONNAIRE

Date_____Name_____ Rate/Rank_____

Watch Station_____ Time off watch_____

1. How long were the dim white lights on?
2. How does this dime white compare with the previous night's light (Previous night was red/white)? Better, worse or same?_____
3. Was the light too dim, too bright, just right?_____
4. Were other lights distracting or annoying?_____
5. If so, which ones?
6. Were your eyes less fatigued, more fatigued, or same as last night?
7. Could you see more clearly, less clearly, or the same than previous night?
8. Comments:

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